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Volume 14 Article 54

4-1-1987

Research Notes : United States : Evaluation of soybean germplasm for stress tolerance and biological efficiency towards ; Air Pollution

G. Gupta
University of Maryland

R. B. Dadson
University of Maryland

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Recommended Citation

Gupta, G. and Dadson, R. B. (1987) "Research Notes : United States : Evaluation of soybean germplasm for stress tolerance and biological efficiency towards ; Air Pollution," *Soybean Genetics Newsletter*: Vol. 14 , Article 54.
Available at: http://lib.dr.iastate.edu/soybeangenetics/vol14/iss1/54

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ALABAMA A&M UNIVERSITY
Department of Plant and Soil Science
Normal, AL 35762

1) Evaluation of soybean germplasm for stress tolerance and biological efficiency.

Objectives: To evaluate soybean germplasm and cultivars for stress tolerance toward moisture stress, pests, harvest index, micronutrients, diseases, nitrogen fixation and air pollution.

Moisture Stress - (B. Kpoghomou, V. T. Sapra and C. Beyl; Alabama A&M University, Alabama)

Three soybean cultivars, 'Lee-74', 'Wright', and 'RA 401', were subjected to 100% (control), 75%, and 50% of field capacity during vegetative (V1), flowering (R2), and pod-filling (R4) stages in greenhouse and field studies. Stress applied at R2 significantly reduced the yield in the greenhouse, while in the field, the maximum reduction was observed when the plants were subjected to stress at R4. Stress during V1 reduced the yield components less than stress applied during R2 or R4 stages in both studies. The pod number and seed weight were the yield components most affected by drought stress, and the number of seeds per pod the least affected. Yield stress index was significantly correlated with the yield and its components. The reproductive stage was clearly more sensitive to drought than the vegetative stage. The cultivar Lee 74 had the highest yield and the second highest yield stress index, whereas the cultivar RA 401 had the lowest yield (Table 1). Yield stress index was determined as: yield of stress treatments/yield of control plants x 100.

Pests - (M. Rangappa, M. E. Kramer and P. S. Benepal, Virginia State University, Virginia)

One of the major objectives of the proposal is systematic screening of all available soybean germplasm of Maturity Groups III to VIII for a natural resistance to a major insect pest, the Mexican bean beetle (MBB). These six Maturity Groups (III-VIII) cover about 5,000 plant introductions (PIs), 350 commercial varieties, and 80 breeding lines. Selected accessions of the most resistant (35% or less leaf defoliation) and highly susceptible (over 75% leaf defoliation) in general screening under field conditions were reevaluated in triplicate in 1985 and in quadruplicate in 1986 (Table 2). About 20 special selections were evaluated for MBB under controlled environmental conditions.

The research group at Virginia State University has developed a sophisticated MBB-rearing technique in the laboratory. Through this technique, each year an average of 25,000 to 30,000 adult MBB and different instar larvae are reared in the laboratory and released into the field experimental plots, thus creating high intensity levels of insect pressure to separate those accessions possessing high levels of natural resistance from those with low levels of resistance.

Besides the major thrust of screening for MBB, other secondary insect pests damage on soybean such as Japanese beetle, corn earworm, loopers, etc., air pollutants (O_3) sensitivity, virus symptoms and appropriate agronomic characteristics were recorded and incorporated into the data base for analysis.

An inducible defensive mechanism in soybean leaves, the trypsin inhibitors have been identified by using isoelectric focusing and gel electrophoresis in the process of working out mechanisms of resistance. Virginia State University takes pride in stating that this is the first such report in the literature of trypsin inhibitors in soybean leaves.

Harvest Index - (A. Bhagsari, Fort Valley State College, Georgia)

Eighteen soybean genotypes, six each from Maturity Groups (MG) V, VI, and VII were planted in four-row (6 m long and 0.9 m wide) experimental plots in a randomized complete block, with four replications, under field conditions using standard cultural practices. The objective was to determine seed yield efficiency (SYE), phytomass accumulation and leaf area index (LAI) development and other physiological and morphological traits and their relationships to yield. Significant differences were found in most of the parameters studied. The range in SYE was 45.2 to 52.1%, 46.5 to 54.7% and 43.9 to 48.3% for MGs V, VI and VII, respectively (Table 3). The new experimental lines, G81-152 (MG VI) had the highest SYE. Grain yield differed significantly within MGs and two genotypes ('Lefore' and 'G98-234') had grain yield of over 4 MT/ha. During September, phytomass yield varied from 6.6 MT/ha for 'Davis' to 12.3 MT/ha for 'Centennial' in MG VI. Generally, high-yielding genotypes also accumulated higher phytomass than low-yielding ones. During July, 60 days after planting, LAI varied from 1.6 to 3.2, 3.2 to 5.5 and 3.2 to 5.1 for MGs V, VI and VII, respectively. Within each MG, high yielding genotypes maintained higher LAI than the other genotypes near maturity.

Grain yield was significantly correlated ($r = +0.74 - 0.83$) to LAI, phytomass ($r = +0.78 - 0.96$) and number of pod-bearing branches ($r = +0.79$). Highly significant correlation coefficients were also found between LAI and total phytomass (Table 4). Within each MG, grain yield was significantly correlated with phytomass. Seed yield efficiency showed no significant correlation.

(J. Joshi and R. Padson, University of Maryland, Maryland)

Selected cultivars from Maturity Groups III, IV, and V were evaluated for the relationship between harvest index (H.I.) and other plant traits. Six PIs with high H.I., six with low H.I. and one adapted variety were included in the experiment from each of the three Maturity Groups.

Previous data (1985) had shown a wide range of H.I. in each Maturity Group. Harvest index ranged from 0.39 to 1.36 from 0.41 to 1.38 in MG IV and from 0.35 to 1.52 in MG V.

Table 1. Plant height, yield, and yield stress index of three soybean cultivars under drought stress during V1, R2, and R4 stages in the greenhouse

		25% of field capacity			50% of field capacity		
Cultivar	Control	V1	R2	R4	V1	R2	R4
	Plant height (cm)						
Lee 74	28.89 b[+]	18.33 b	18.33 b	27.33 ab	15.33 a	28.33 a	29.33 b
Wright	30.63 a	21.17 a	29.83 a	31.16 a	17.70 a	31.17 a	32.83 a
RA 401	26.22 b	17.50 b	26.00 b	25.50 b	14.66 a	24.50 b	24.10 c
	Yield plant^{-1} (g)						
Lee 74	27.23	19.22 b	13.70 a	15.48 b	15.91 a	7.75 a	10.12 b
Wright	30.23	20.85 a	14.51 a	17.75 a	18.33 a	5.64 b	13.71 a
RA 401	22.29	17.72 b	11.82 a	13.85 b	12.26 a	7.63 ab	9.30 b
	Yield stress index (%)						
Lee 74		67.03 b	52.22 a	56.67 a	55.40 a	29.59 a	37.12 b
Wright		68.18 b	45.97 a	62.58 a	60.00 a	17.90 b	48.33 b
RA 401		82.43 a	50.79 a	63.20 a	57.30 a	32.98 a	42.81 b

[+]Means within a column followed by the same letter are not significantly different at the 0.05 probability level using Duncan's Multiple Range Test.

Table 2. Total soybean germplasm screened for Mexican bean beetle in the field and final selections

Maturity groups	Screened germplasm				Selections	
	PIs	Cultivar	Breeding lines	Total	Most resistant	Highly susceptible
III	1087	38	3	1128	17	15
IV	2240	52	9	2301	10	5
V	1369	43	12	1424	65	12
VI	421	33	15	469	45	15
VII	314	28	8	340	34	11
VIII	266	12	6	284	13	10
Total	4697	206	53	5946	184	68

Table 3. Seed yield efficiency, grain yield, phytomass, and number of pod-bearing branches in soybeans (1986)

	Seed yield efficiency	Grain yield	Phytomass					Pod-bearing	
			9 Oct	25 Sept	4 Sept	18 Aug	21 July	branches	nodes
	%	MT/ha						Number/plant	
Group V									
417.172	52.10	2.23	4.28	4.26	4.97	5.27	1.77	3.16	8.00
416.838	51.89	2.32	4.42	3.45	4.28	4.98	2.06	3.00	8.41
416.447	47.66	1.92	4.04	6.87	5.13	3.63	2.10	3.66	9.42
Essex	46.00	2.75	5.99	4.27	6.44	3.86	2.40	4.42	9.00
417.356	45.90	2.73	5.97	4.56	4.57	4.77	2.66	4.66	9.00
417.493	45.17	1.88	4.12	4.97	7.01	3.76	2.39	4.33	8.17
Group VI									
G81-152	54.70	3.74	6.85	10.16	9.34	7.11	4.29	5.33	8.25
Davis	54.17	2.98	5.51	6.63	6.62	4.62	2.88	3.00	10.50
G98-234	49.29	4.05	8.27	10.09	7.91	5.47	3.22	6.41	8.08
Tracy	49.09	2.90	5.97	8.72	5.23	5.20	2.41	4.75	9.58
Centennial	46.68	3.73	7.98	12.31	9.01	5.83	3.00	6.75	10.50
Leflore	46.54	4.12	8.83	11.49	5.94	7.31	3.54	5.75	9.41
Group VII									
G80-1011	48.28	3.06	6.32	8.00	4.97	4.04	2.17	5.25	9.33
Ransom	47.64	3.13	6.59	5.59	5.60	4.47	2.60	4.79	8.54
Braxton	47.29	3.18	6.73	6.16	4.20	3.00	2.18	5.92	10.75
G80-1413	46.41	3.89	8.34	11.67	7.66	7.68	3.20	6.16	9.18
Wright	46.07	3.01	6.75	7.64	5.74	5.56	2.62	4.42	9.17
Gordon	43.87	3.54	8.07	10.23	5.77	7.36	3.96	6.91	10.16
L.S.D. (0.05) (within groups)	4.83	0.51	0.92	2.79	2.88	1.42	1.37	1.97	1.26

Table 4. Correlation coefficients (γ) for soybeans (1986)

	Grain yield	Total phytomass
^{z}LAI Oct 9	$+0.42^{N.S.}$	+0.51*
LAI Sept 25	+0.83**	+0.86**
LAI Sept 4	+0.80**	+0.75**
LAI Aug 18	+0.80**	+0.79**
LAI July 21	+0.74**	+0.70*
No. pod bearing branch	+0.79**	+0.86**

^{z}LAI (Leaf Area Index).

*,**Significant at 5% and 1% levels of probability, respectively.

N.S. = Not significant.

Micronutrients - (M. R. Reddy, North Carolina A&T State University, North Carolina)

A greenhouse study was conducted to evaluate the sensitivity and tolerance of various soybean genotypes to high levels of soil manganese, and to strongly acid soil conditions. Forty-four soybean genotypes in Maturity Groups V, VI, VII, and VIII were evaluated, the soil used for the study was very high in manganese (90 ppm) and strongly acidic (pH 4.8), and was collected from Buncombe County, North Carolina. The soil pH levels were pH 4.8 (original soil pH), and pH 6.3.

Genotypes PI 200506, FC 31737, FC 417136, PI 123440, PI 89469, L-76-0049, 'Coker 237', and 'Bedford' were sensitive to high levels of manganese and low soil pH; seed yield decreased significantly at pH 4.8. These genotypes did well at pH 6.3 and gave significantly higher seed yield. Genotypes PI 381668, FC 31665, PI 417063, PI 416900, PI 960895, PI 159319, PI 170891, PI 181565, and some others were not sensitive to high manganese and low soil pH, and their seed yield was not significantly different under the different soil pH levels (Table 5). Genotypes PI 200474, PI 229358, PI 416893, PI 416937, PI 417134, and 'Deltapine' were tolerant to high soil manganese and to low soil pH, but did not do well at higher soil pH (pH 6.3), resulting in lower seed yield (Table 6). The genotypes that were sensitive to high soil manganese showed higher concentration of manganese in leaf tissue compared with the tolerant genotypes (Table 7).

Diseases - (R. P. Pacumbaba and V. T. Sapra, Alabama A&M University, Alabama)

A field study was conducted for screening and selection of improved soybean germplasm for disease resistance in 1986. The soybean crossing block consisted of 207 germplasm entries screened at flowering and at maturity. One hundred and one were resistant and moderately resistant to bacterial blight (BB). Thirty soybean germplasm entries supplied by Auburn University

Table 5. Soybean genotypes tolerant to high soil manganese and low soil pH, with similar yield under different soil conditions

Soybean genotype	Soil pH 4.8 (high soil Mn)	Soil pH 6.3 (low soil Mn)
	Seed yield (g/pot)	
PI 96089	5.0	5.5
PI 159319	11.1	12.4
PI 159322	6.2	7.1
PI 170891	8.5	7.9
PI 171442	5.3	5.6
PI 181565	9.7	8.9
PI 230978	6.8	6.7
PI 279621	7.3	7.1
PI 324068	6.5	5.5
PI 379618	6.8	7.1
PI 381668	8.3	9.3
PI 416900	7.4	7.1
PI 417063	8.1	8.0
PI 417123	5.8	6.4
PI 417258	6.5	7.2
PI 423824	5.6	5.4
PI 423986	5.6	6.2
PI 960895	7.1	8.6
FC 31665	7.2	8.6
L-76-0132	7.2	5.7
Easy Cook	6.7	6.7

Table 6. Soybean genotypes tolerant to high soil manganese and low soil pH, with lower yield at higher pH

Soybean genotype	Soil pH 4.8 (high soil Mn)	Soil pH 6.3 (low soil Mn)
	Seed yield (g/pot)	
PI 200474	8.4	6.5
PI 229358	7.6	5.1
PI 416893	10.2	8.1
PI 416937	9.7	5.7
PI 417134	9.4	7.2
Deltapine	8.8	6.1

Table 7. Differential uptake of manganese by various soybean genotypes

Soybean genotype	Soil pH 4.8 (high soil Mn)	Soil pH 6.3 (low soil Mn)
	Leaf Mn (μg/g)	
Sensitive to Mn		
PI 200506	437	200
L-76-0049	282	190
Bedford	277	198
Tolerant to Mn		
PI 159319	247	192
PI 170891	255	189

for breeding purposes were also screened for disease resistance. Twenty-four were resistant to soybean stem canker (SSC), two and ten were resistant and moderately resistant to BB. Rating for soybean cyst nematode (SCN) was not included because the soybean was planted in non-SCN infested soil. In the Uniform Soybean Test, 13 germplasm entries (selected from an earlier study) were used. Six and 13 germplasm entries were moderately resistant to SCN and BB, respectively, while 12 and one entries were resistant and moderately resistant to SSC. In the soybean collection of the RR3 project, 58 entries were screened for resistance to SSC and BB. Forty-one entries were found resistant to SSC and one and eight were resistant and moderately resistant to BB. Five germplasm entries showed multiple disease resistance ('Laneer', 'Jeff', 'AM 1026', PI 157476, and 606).

Nitrogen Fixation - (M. Floyd and S. Mookherji, Alabama A&M University, Alabama)

Sixty-five soybean germplasm lines from maturity groups (MG) IV to VIII were evaluated for their acid (pH 4.4) and Al (6 ppm) tolerances by measuring their N_2 fixing capabilities with USDA rhizobium strain 110 and mixture of strains 110, 6, and 122. Plants were grown in a growth chamber in nitrogen-free nutrient solution for 35 days. Plant introductions from MG VI had consistently higher ($\geq$ 100%) relative root length in 6 ppm Al nutrient solution than those lines from other MGs. Germplasm lines within MG VII had the highest nodule numbers (16.5) per plant (Fig. 1) and also the highest nitrogenase activity (4.68 μmole C_2H_4/plant/hour) (Table 8). A comparison of the means of N-fixing traits showed that germplasm lines within MG VII performed better than lines from MG V and VI at pH 4.4 (Table 9). Germplasm 'Deltapine 246', 'Deltapine 560', and PI 416893 had the best symbiotic response.

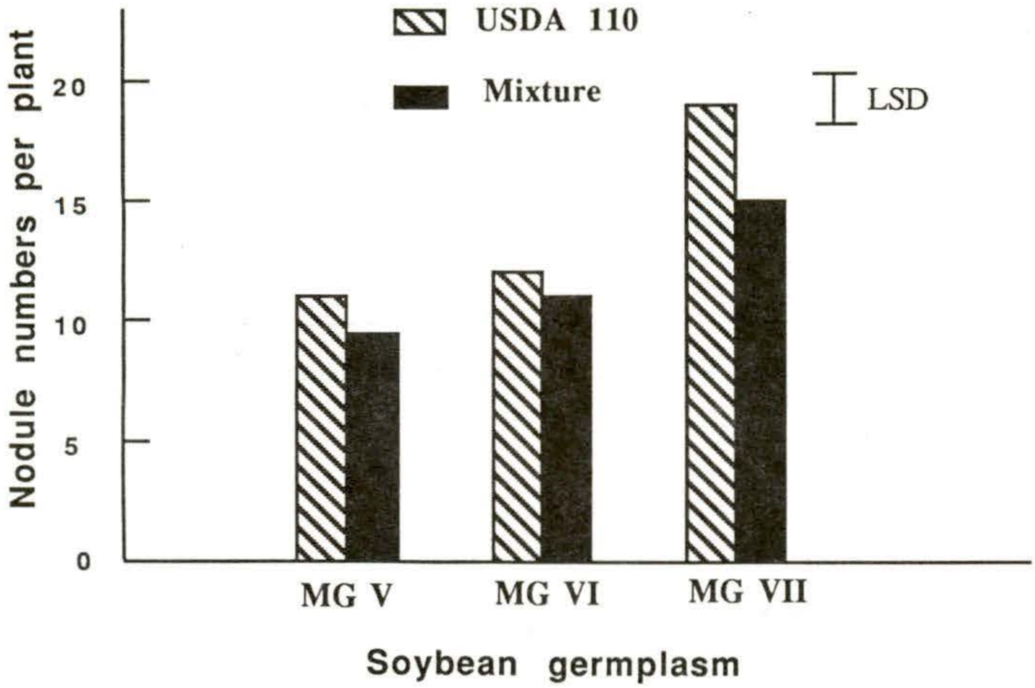

Fig.1 Effect of Rhizobia Strains on Nodule Numbers

Table 8. Comparisons of means of N-fixing traits of soybean germplasm lines from MG V-VII at pH 4.4

Soybean germplasm	Nodule no. per plant	ARA μ mole C_2H_4/hr/plant	Total % N in shoot
MG V	9.95 b**	2.86 b	3.42 a
MG VI	11.59 b	3.45 b	3.80 a
MG VII	16.47 a	4.68 a	4.00 a

**Numbers followed by the same letters within columns are not significantly different at p = 0.05 by DMRT.

Table 9. Symbiotic performance of soybean germplasm lines from MG VII at pH 4.4 inoculated with USDA 110

Soybean germplasm lines	Nodule number per plant	ARA µmole C_2H_4/hr/plant	Total % N
Deltapine 246	14.53 bc**	3.59 bc	4.47 a
Deltapine 560	20.70 ab	4.34 ab	4.40 a
PI 416893	22.33 a	8.12 a	3.57 b

**Means followed by the same letter are not significantly different at probability = 0.05 by DMRT.

Air Pollution - (G. Gupta and R. B. Dadson, University of Maryland, Maryland)

Relationships between the three major ambient air pollutants - ozone (O_3), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) - have been explored experimentally using linear regression analysis. It has been shown that the amount of O_3 in ambient air is based on the total amount of SO_2 + NO_2 and that the concentration of O_3 can be predicted from the concentration of SO_2 + NO_2. On the basis of the data collected, a modified NO_2 - O_3 photolytic cycle has been proposed taking into account dry precipitation of SO_2 and NO_2.

One-month-old soybean cultivar 'Williams' was exposed to NO_2 at 0.5 and 0.1 ppm concentration in growth chambers for only 7 hours. Data were collected both on net photosynthetic rate (before exposure, immediately following exposure and 24 hours after exposure) and yield (pod number, seed number and dry seed weight per plant). Net photosynthetic rates immediately following exposure to 0.5 and 1.0 ppm NO_2 treatment decreased by 18% and 27%, respectively, compared with the control plants exposed to carbon filtered air. Reductions in yield were observed with both the 0.5 and 1.0 ppm NO_2 treatments. The reduction in yield was linearly related to NO_2 concentration; with 0.5 and 1.0 ppm NO_2, the yield (seed weight per plant) reduction was 35 and 60%, respectively. Waller Duncan - K ratio t test and the Tukey's studentized range (LSD and MSD) tests showed that the treatments were significantly different at 0.05 level both for reduction in photosynthesis immediately following exposure and yield data.

The study on the effects of 0.0, 0.1, 0.2, 0.3, and 0.5 ppm levels of NO_2 exposure on soybean cultivar Williams in relation to photosynthesis, protein content, chlorophyll content, membrane permeability, biomass, and yield data is in progress. Other cultivars also will be studied with the long-range objective of learning the combined effects of O_3, SO_2 and NO_2.

UNIVERSITY OF MISSOURI - COLUMBIA
Delta Center
Portageville, MO 63873

1) An improved greenhouse method of evaluation for inheritance of resistance to race 4 of soybean cyst nematode.

Studies to determine mode of inheritance of resistance to soybean cyst nematode (SCN), *Heterodera glycines*, could be influenced by the methods of evaluation in use. Any improvement in growing conditions of the host and pathogen, superior inoculation techniques, inducement of desirable infection in the host with minimum genetic variability in the SCN population could result in optimum expression of full complement of genes conferring resistance to SCN races.

Our objective was to determine the mode of inheritance of resistance in Soybean Plant Introduction PI 88.788 for SCN race 4 reaction, using the improved techniques of evaluation.

Crosses were made in the field during summer between resistant parent PI 88.788 and susceptible parents 'Peking' and 'Forrest'. The F_1 and F_2 plants were grown in Puerto Rico and University of Missouri-Columbia Delta Center, Portageville, to obtain F_2 and F_3 seeds, respectively. Care was taken to grow plants in fields without SCN infestation.

The F_2 plants, their parents, and a set of standard host differentials, with 'Essex' as susceptible check, were evaluated in the greenhouse. The basic techniques of evaluation and methods for preparation of purified SCN race 4 inoculum were the same as used by Anand and Brar (1983) and Rao-Arelli and Anand (1986).

Some of the improvements include: (1) selection, reproduction of SCN race 4 field populations on susceptible PI line 90.763 for more than 30 generations under isolation in the greenhouse to minimize the existing genetic variability; (2) preparation of inoculum from freshly picked white females found on the roots of PI 90.763 and crushed to release eggs for obtaining synchronized hatching; (3) using inoculum entirely consisting of eggs and placing in direct contact with the host roots for quicker hatching and efficient utilization of all available infestation sites; (4) an aquarium air-blowing pump was used to keep eggs constantly in uniform suspension, so as to dispense approximately same number of eggs in each inoculation.

The reaction of the plants for race 4 is presented in Table 1. The Index of Parasitism (IP) was calculated [(number of cysts on a given PI line/ number of cysts on susceptible, Essex) x 100]. The reaction was expressed positive or susceptible where IP was 10% or more (Golden et al., 1970).

Of the 200 F_2 plants tested from the cross Forrest x PI 88.788, 25 were resistant and 175 were susceptible. The cross of Peking and PI 88.788 segregated 22 resistant:177 susceptible in F_2. The segregation in both crosses could be explained based on two dominant genes and one recessive gene in PI 88.788 conditioning resistance to SCN race 4.

Table 1. Reaction of soybean parents, F_2 plants, host differentials and Essex to *Heterodera glycines* race 4

Entry	Number of plants Resistant	Number of plants Susceptible	Expected ratio	χ^2 value	P value
Peking	0	10			
Forrest	0	10			
PI 90.763	0	10			
PI 88.788	10	0			
Essex	0	10			
Forest x PI 88.788 (F_2s)	25	175	9(R):55(S)	0.36	.50-.70
Peking x PI 88.788 (F_2s)	22	177	9(R):55(S)	1.47	.20-.30

Several genes conditioning resistance to SCN races were reported in soybean lines Peking, PI 90.763 and PI 88.788 by Caldwell et al. (1960), Hancock et al. (1985), Hartwig and Epps (1970), Matson and Williams (1965) and Sugiyama and Katsumi (1966). Thomas et al. (1975) indicated that resistance to SCN race 4 was conferred by a single recessive gene pair in the cross PI 88.788 x Peking.

The F_2 results obtained in our studies appear to indicate a more complex nature of inheritance for controlling SCN race 4 resistance in PI 88.788. Presumably, the expression of full complement of genes to SCN race 4 in PI 88.788 occurred with the use of some of the improved techniques of evaluation available today. Of course, evaluation of F_3 families would confirm the results obtained in F_2 generations.

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A. P. Rao-Arelli
Sam C. Anand